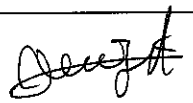
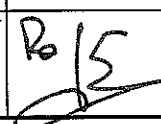
 DIVISION TECHNIQUES AVANCEES		PROCES-VERBAL D' ESSAI TEST REPORT CRYOGENIC TURBO EXPANDER		N° : C 4023 NT 13 (0) Folio : 1 / 11 Folio :	
AFFAIRE : KSTAR JOB :		N° : T06 N° :		Fiche Suiveuse n° : Inspection traveller n° :	
Identification du matériel : C4 Material identification :		N° : 556 FX1		Quantité / Quantity : 1 Lot / Batch :	
Fournisseur/Fabricant : Supplier / Manufacturer : AIR LIQUIDE		Organisme de Contrôle : Inspected by : D2TI		Lieu : Location : Sassenage	
Documents de référence : Reference documents : PROCEDURE : D4444-PO-2		Instruments de contrôles utilisés : Inspection instruments used :			
		Type / Type Test bed		N° de Gestion/Control n° 504 9999 100	
MESURES		RESULTATS		OBSERVATIONS	
PIVOTERIE / BEARINGS		Passed			
VITESSES CRITIQUES Critical speeds		Passed			
SURVITESSE / Overspeeds		Passed			
START/STOP		Passed			
DESCENTE EN FROID Cold down		Passed		Limited by our test bench	
RENDEMENT / Efficiency		Passed			
DECISION : DECISION : CONFORME / PASS <input checked="" type="checkbox"/> NON CONFORME / FAIL <input type="checkbox"/>		OBSERVATIONS : COMMENTS :			
	ESSAI / TEST	Responsable / Manager		A.Q. / Q.A.	
NOM / NAME	B Renzetti	F. Delcayre		JL. David	
DATE / DATE	30/11/06	30/11/06			
SIGNATURE / VISA	 				

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1. SCOPE

This report is a summary of the tests of a Cryogenic turbo-expander cartridge, performed on DTA test bed according to the procedure D4444-PO-2.

2. PROCESS CONDITION

The data sheet in appendix gives the turbine process conditions specified by the customer.

3. GAS USED FOR THE TEST

Helium

Nitrogen

4. BEARING CONDITIONS

The diagrams in appendix give the gas bearing conditions :

- to be applied on site,

- to be applied during the test.

5. ANNEXES

TESTS REPORTS

TEST REPORT

5.1 THRUST BEARING TEST, LOW SPEED

(Items 6.1 of procedure)

Cartridge number : C4 556 FX1

Bearing conditions required : NORMAL

CASE	EXTREME 1	EXTREME 2	
INPUTS			
Load	0	135	N
On	Brake	Turbine	Bearing
Equivalent pressure difference on the shaft	0	10	10 ⁵ Pa
OUTPUTS			
Inlet bearing pressure	11.42	11.55	10 ⁵ Pa
Outlet bearing pressure	2.76	3.01	10 ⁵ Pa
Turbine outlet pressure (1)	2.77	3.02	10 ⁵ Pa
Brake pressure (2)	2.99	13.03	10 ⁵ Pa
Pressure difference = (2) – (1)	0.22	10.01	10 ⁵ Pa
Speed	12	9	Hz
Passed/failed	passed	passed	

TEST REPORT

5.2 THRUST AND JOURNAL BEARINGS TEST, HIGH SPEED

(Items 6.2 of procedure)

Cartridge number : C4 556 FX1

Bearing conditions required : NORMAL

MODE	MINIMAL	NOMINAL	MAXIMAL	
INPUTS				
Turbine outlet design pressure (1)	3.5	3.0	2.4	10 ⁵ Pa
Brake design pressure (2)	10.0	12.5	15.1	10 ⁵ Pa
$\Delta = 2-1$	6.5	9.5	11.7	10 ⁵ Pa
OUTPUTS				
Inlet bearing pressure	11.48	11.48	11.44	10 ⁵ Pa
Outlet bearing pressure	2.97	3.05	2.94	10 ⁵ Pa
Turbine outlet test pressure (1)	3.05	3.11	3.04	10 ⁵ Pa
Brake test pressure (2)	9.48	12.69	14.81	10 ⁵ Pa
$\Delta = (2) - (1)$	6.43	9.58	11.77	10 ⁵ Pa
Speed	1103	913	824	Hz
Passed	passed	passed	passed	

TEST REPORT

5.3 THRUST AND JOURNAL BEARING TEST, HIGH SPEED

(Items 6.2 of procedure)

Cartridge number : C4 556 FX1

Bearing conditions required : ALARM AND STOP

BEARING CONDITIONS	ALARM	STOP	
Mode	Nominal	Nominal	
INPUTS			
Turbine design outlet pressure (1)	3.0	3.0	10 ⁵ Pa
Brake design pressure (2)	12.5	12.5	10 ⁵ Pa
$\Delta = 2-1$	9.5	9.5	10 ⁵ Pa
OUTPUTS			
Inlet bearing pressure		10.92	10 ⁵ Pa
Outlet bearing pressure		2.98	10 ⁵ Pa
Turbine outlet test pressure		3.06	10 ⁵ Pa
Brake inlet pressure		9.52	10 ⁵ Pa
$\Delta = 2-1$		6.46	10 ⁵ Pa
Speed		926	Hz
Passed		passed	

TEST REPORT

5.4 CRITICAL SPEEDS AND SHAFT VIBRATIONS

(Items 6.3 of procedure)

Cartridge number : C4 556 FX1

Bearing conditions required : STOP

INPUTS					
	1 st RIGID MODE		2 nd RIGID MODE		
Calculated peak freq.	640		720		Hz
OUTPUTS					
Measured critical speeds	BEGIN.	END	BEGIN.	END	Hz
		700		850	
Sound level estimation	B		B		
Time within the mode (> 3 ')	3		3		Min
Inlet bearing pressure	11.49		11.49		10 ⁵ Pa
Outlet bearing pressure	2.94		2.94		10 ⁵ Pa
Fail/pass	passed		passed		

Sound level estimation :

A : Inaudible

B : Perceptible

C : Noisy

D : Excessive

TEST REPORT

5.5 OVERSPEED TEST

(Items 6.4 of procedure)

Cartridge number : C4 556 FX1

Bearing conditions required : NORMAL

INPUTS				
Nominal speed (Hz)		Maximum speed (Hz)		Over speed (Hz)
928		1050		1125
OUPUTS				
BEARING TEST CONDITIONS				
BEARING GAS PRESSURE (10 ⁵ Pa)		BEARING GAS TEMPERATURE (°C)		BEARING GAS FLOW RATE (g/s)
SUPPLY	RETURN	SUPPLY	RETURN	
11.44	2.98	16.5	23	3.09

TURBINE TEST CONDITIONS

TURBINE PRESSURE (10 ⁵ Pa)		TURBINE TEMPERATURE (K)		TURBINE FLOW RATE (g/s)
SUPPLY	RETURN	SUPPLY	RETURN	
16.49	3.08	244.3	228.1	32.9

BRAKE TEST CONDITIONS

INLET BRAKE PRESSURE 10 ⁵ Pa	OUTLET BRAKE TEMPERATURE °C
8.49	46.2

TEST RESULTS

ROTATION SPEED Hz	STEADY STATE	OVERSPEED STATE DURATION (mn)	COMMENTS	
			FAIL	PASS
1140	A	3		X

Steady state evaluation

A : Stable

B : Noisy

C : Unstable

TEST REPORT

5.6 COOL DOWN, START-UP AND SHUT-DOWN

(Items 6.5 and 6.6 of procedure)

Cartridge number : C4 556 FX1

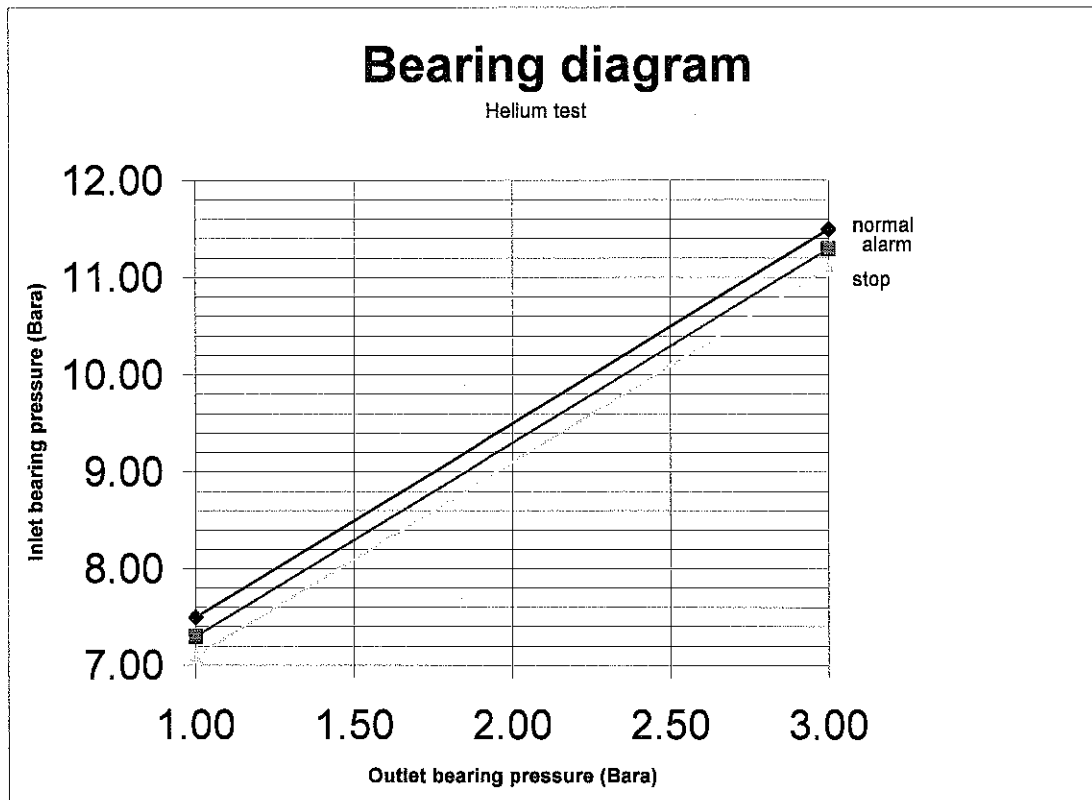
Bearing conditions required : normal

Nominal speed :

	AMBIENT	MEDIUM	+10 %	NOMINAL	-10 %	
Target outlet temperature	280	150	6	5.3	4.8	K
TURBINE :						
Inlet pressure	15.97	14.56		17.96		10 ⁵ Pa
Outlet pressure	3.11	3.08		3.10		10 ⁵ Pa
Inlet temperature	281.6	160.4		20.1		K
Outlet temperature	267.3	150		13.0		K
Flow	29.2	34.7		145		g/s
U ₁ / Co	0.08	0.12		0.49		
η_s	11	15		64		
BRAKE :						
Inlet pressure	11.64	9.5		5.65		10 ⁵ Pa
Outlet temperature	29	40.5		61.2		°C
BEARING :						
Inlet pressure	11.44	11.48		12.35		10 ⁵ Pa
Outlet pressure	3.0	2.96		2.94		10 ⁵ Pa
Inlet temperature	17	16.7		17.8		°C
Outlet temperature	19.4	17.1		9.8		°C
Inlet flow	2.91	3.0		3.36		g/s
SPEED :	927	998		1455		Hz
Number of start up/shut down	X	3	X	3	X	
Fail/pass	passed	passed	passed	passed	passed	

AFFAIRE / JOB :KSTAR

N° :

Identification du matériel / *Material identification* : C4 556 FX1APPLICATION : Site Client/*Customer* DTA Test

NOM / NAME	F. DELCAYRE				
DATE / DATE	02/10/06				
SIGNATURE / VISA					
VERSION / ISSUE					

TEST REPORT
5.7 EFFICIENCY VERSUS U1/CO

(Items 6.7 of procedure)

Cartridge number : C4 556 FX1

INPUTS
TURBINE PROCESS CONDITIONS

GAS	PRESSURE 10 ⁵ Pa		TEMPERATURES K		FLOW kg/s	ENTHALP. DROP kJ/kg		η^s $\Delta \text{Hr} / \Delta \text{Hs}$	ROTATION SPEED Hz	REFRIG. POWER Watt	INLET WHEEL PRESS. 10 ⁵ Pa
	INLET	OUTLET	INLET	OUTLET		ΔHs	ΔHr				
He	20.47	3.0	6.46	5.3	294.0	12.8	9.3	0.73	928	2745	11.9

OUTPUTS
TURBINE TEST CONDITIONS

GAS	PRESSURE 10 ⁵ Pa		TEMPERATURES K		FLOW kg/s	ENTHALP. DROP KJ/kg		η^s $\Delta \text{Hr} / \Delta \text{Hs}$	ROTATION SPEED Hz	REFRIG. POWER Watt	INLET WHEEL PRESS. 10 ⁵ Pa
	INLET	OUTLET	INLET	OUTLET		ΔHs	ΔHr				
He	17.96	3.1	20.1	13.0	145	50.526	32.363	0.64	1455	4098	8.21

BEARING TEST CONDITIONS

GAS	PRESSURE 10 ⁵ Pa		TEMPERATURES °C
	SUPPLY	RETURN	
He	12.35	2.94	In : 17.8 Out : 9.8

BRAKE TEST CONDITIONS

GAS	PRESSURES 10 ⁵ Pa		TEMPERATURE °C
	INLET	OUTLET	
He	5.65		61.2

TEST RESULTS

DIAM. WHEEL mm	TIP VELOCITY U ₁ m/s	SPOUTING VELOCITY C ₀ m/s		U ₁ / C ₀	η^s	COMMENTS	
		SUPPLY	RETURN			FAIL	PASS
34.0	155.4	317.8	0.49	64 %			X

UTILITY FLOW RATE

GAS BEARING SUPPLY g / s	BRAKE SUPPLY g / s	SEAL GAS g / s	RETURN g / s
3.36	0.26	0.33	3.99